

Fine structure interpretation and reservoir forming characteristics analysis of Jurassic Badaowan Formation in Madong area of Xiayan fault zone

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Abstract. Fine structural interpretation is one of the effective methods to find favorable structural traps and targets. Aiming at the fault interpretation of Jurassic Badaowan Fm in Madong area of Xiayan fault zone is not fine and structural characteristics are not implemented, the structural characteristics of Jurassic Badaowan Fm are implemented and favorable traps are found through the study of seismic, well logging and geological comprehensive methods. The results show that the structure of Jurassic Badaowan Fm in Madong area is high in the north and low in the south. The first member of Badaowan Fm is a delta front subaqueous distributary channel deposit, which is a hydrocarbon enrichment zone. Oil and gas are adjusted along the relay of deep and shallow faults, and the great fault zone and the inherited uplifting zone are favorable accumulation areas of Jurassic Badaowan Fm in Madong area. In this paper, the relationship between deep and shallow fault system and hydrocarbon distribution of Badaowan Fm in Madong area is systematically reviewed for the first time. Combined with the palaeohigh distribution, three favorable hydrocarbon accumulation zones are identified, which provides favorable targets for exploring the hydrocarbon accumulation potential of Badaowan Fm.

1. Introduction

The Madong area of Xiayan fault zone is located at the junction of Xiayan uplift and Sangequan uplift in the central zone of Junggar basin[1], which was formed during the late Hercynian tectonic movement from the end of Devonian to Permian. During the Yanshanian tectonic movement, the tectonic movement of the basin from Jurassic to Cretaceous was more oscillatory and frequently uplifted, resulting in multiple unconformities on the stratum. Dabasong Uplift is located in the south, Sangequan Uplift is located in the north, and it is connected with Mahu Depression in the west. It is on the path of migration and accumulation of mature oil and gas from the depression to Luliang Uplift[2], with favorable structural location and great exploration potential[3-4].

In recent two years, Madong area has achieved breakthrough in oil testing of Jurassic Badaowan Formation, which is beneficial to expand the oil and gas field in Madong area. In September 2020, the first section of Badaowan Formation of Well D132 conducted recovery oil testing at 3396.0-3406.0m. After fracturing, a high-yield industrial oil flow with a daily oil output of 30.69t and a daily water output of 11.9m³ will be obtained, making a breakthrough in Badaowan Formation for the first time. Later, Well D131 and Well D003 were selected to resume oil testing, but the results of oil testing were not as expected. At present, the Badaowan Formation in Madong area has not been systematically and deeply

studied. Problems such as imprecise fault interpretation, unconfirmed structural characteristics and unclear reservoir forming characteristics of Badaowan Formation have seriously restricted the process of oil and gas exploration and development in this area. It is urgent to carry out a deeply seismic and geological comprehensive study on the Jurassic Badaowan Formation in Madong area.

Through fault classification and multi-attribute fault identification technology, the fault is finely delineated, and the fault distribution, fault combination and structural morphology are determined. At the same time, combined with the analysis and interpretation results of known oil and gas producing well, the reservoir forming characteristics of this area are studied to find favorable exploration directions and targets.

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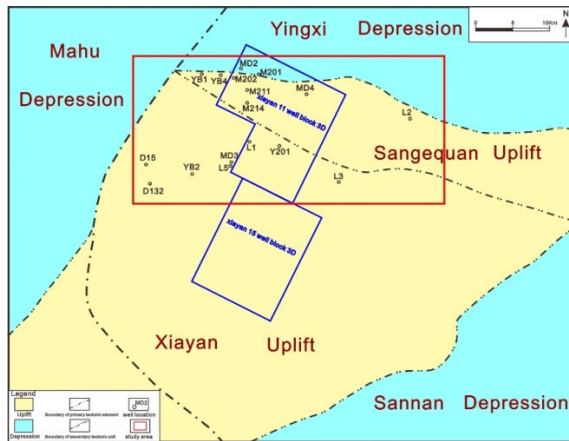


Figure 1 Location Map of Study Area

2. Fine structure interpretation

2.1 Horizon calibration

In order to enhance the fracture characteristics of the profile, this study used the median filtering and structure dip-steering filtering technology to carry out post stack data processing for the 3D data of Xiayan Well 11 area, effectively improving the continuity of seismic events (Fig.2), and greatly enhancing the reliability of fine structure interpretation. At the same time, the combination of well and seismic data completed the division of small layers of Badaowan Formation and the calibration of well and seismic data of key wells (Fig.3). The Jurassic Badaowan Formation in Madong area has a "three section" structure and typical "three section" logging response characteristics. The thick sandstone at the bottom of Bayi Member (J_1b_1) is medium low GR and medium high RT, which is obviously compared with the underlying T_3b thick mudstone (medium high GR and low resistance). The thick mudstone of the Eighth Second Member (J_1b_2) is high GR in the whole section, and the resistance of the Eighth Third Member (J_1b_3) rises in a "step" manner. Sandstone at the bottom of mudstone at the top of J_1b_3 , the bottom sand is the marker bed, and the medium low GR (box and bell structure), SP are obviously abnormal, with low density logging response. The coal seams in the middle and lower part of the section 81 show strong seismic reflection, with high contrast. The geological layering has good consistency on the seismic profile. The layering boundaries of each layer group are marked on the corresponding event with similar reflection characteristics. The horizontal consistency is good. The seismic reflection event and the geological horizon have relatively accurate correspondence (Fig.4).

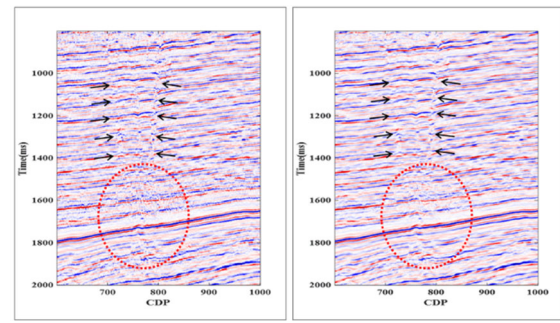


Fig.2 Comparison of 3D Post stack Seismic Data (Inline700) of Xiayan Well 11 area before and after Processing

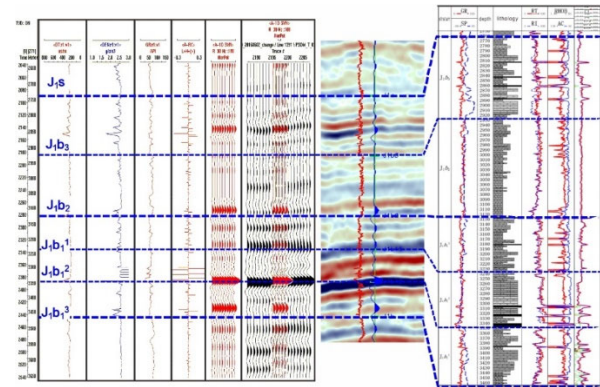


Fig.3 Stratigraphic Division and Synthetic Record Calibration of Jurassic Badaowan Formation in Well D132

2.2 Horizon and fault interpretation

After geological horizon calibration and well series layer connection, seismic profile horizon tracking and vertical and horizontal closure shall be carried out by means of seismic profile, slice, block drift and other means according to reflection structure and wave group characteristics. Select sections with good data quality, clear wave group characteristics and clear section display, give priority to comparison, establish backbone sections, and gradually extrapolate closed sections with poor data quality. The point and line are used for full 3D tracking and comparison to achieve the purpose of fine interpretation.

Most of the faults in the study area are small faults, and the seismic reflection characteristics have no clear dislocation of the same events, which are mainly manifested in the sudden increase or decrease of the same events, sudden change of the shape of the reflection events, scattered reflection or void area, bifurcation, merger, distortion, phase transformation of the events, sudden change of seismic reflection characteristics (frequency, amplitude) and other seismic responses. For such small faults, in addition to conventional coherent volume slicing and along layer attributes, some special technical means are used in the research, such as coherent attribute extraction, ant body feature analysis, curvature attributes and other characteristic coherent recognition techniques using dip steering filtering to process data volume (Fig.4a). Large scale coherence can provide direct evidence of fault combination and muting, while small scale coherence can reflect the fault zone that may occur next to the fault. On this basis, the seismic time slice is

used to depict the local target and the overall structural characteristics, and the recheck of the fault system in the target area is strengthened (Fig.4b).

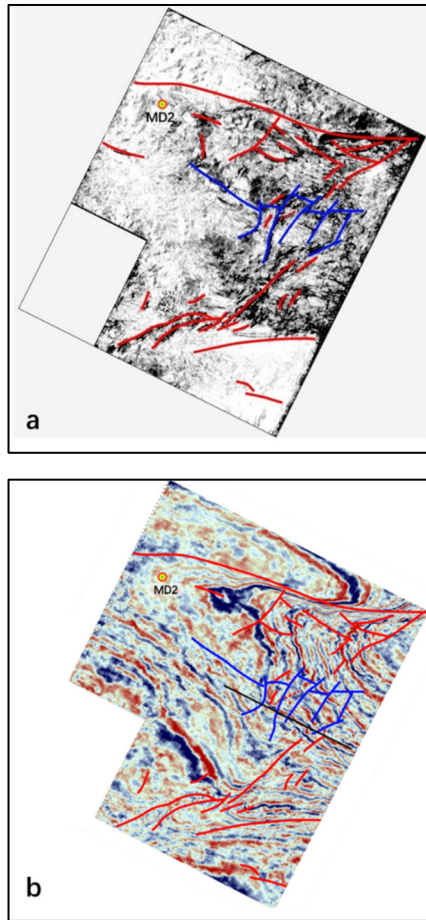


Fig.4 Coherent Attribute Plan and Time Slice of Jurassic Badaowan Formation

2.3 Tectonic characteristics

By using the time-depth relationship of 16 wells in the study area and through the lateral comparison of the time-depth relationship of adjacent wells, the time-depth relationship curve that conforms to the seismic geological rule (the velocity increased with depth) is optimized, and the parabolic time-depth relationship in the middle of the curve is also determined as the comprehensive velocity of the area. In addition, with the time-depth relationship of multiple wells as the control point and horizon and geological stratification as constraints, a high-precision three-dimensional spatial velocity model (Fig.5) is established to convert the time-depth relationship. After the time-depth conversion, the structural map is verified by drilling stratification, the velocity field is feedback adjusted, and the high-precision velocity field is established repeatedly to finally complete the structural mapping.

The stratum thickness of the Bayi Member of the Madong Xiayan Sangekuan uplift in the study area is gradually thinning, and the sedimentation of the Bayi Member and the Bayi Member is relatively stable. The most important oil and gas bearing interval of Badaowan Formation is located in Bayi Member. In order to meet the long-term

demand, the structural map of Bayi Member has been expanded in four directions: east, west, north and south. The previous structural results have been integrated with the structural interpretation results of this paper, forming a complete structural map of the top boundary of Bayi Member in Madong area (Fig.6). The Bayi Member in the study area is characterized by "high in the north and low in the south" structure, and the overall structure is "two bulges, one anticline and one platform". Among them, "two bulges" are Dabasong bulge and Xiayan bulge, "one anticline" is the anticline zone from Well Madong 2 to Well L9, and "one platform" refers to 132 wide and gentle platform areas. Bayi Member in Madong area is located in Dabasong Xiayan Sangekuan inherited uplift structure, and many fault nose and fault block traps similar to Well D132 area are developed, which is a favorable direction area for oil and gas enrichment. Yanshanian faults in Madong area have obvious differences[5]. The main faults of Badaowan Formation and Sangonghe Formation are the same, but the secondary faults are different, which are two periods of faults. The main faults are the same, with large fault displacement, and are the main oil source faults. The secondary faults are inconsistent, which can be divided into Badaowan Formation (J_1b) and Sangonghe Formation (J_1s) faults. The fault throw is small, and it is a local zone and reservoir controlling fault.

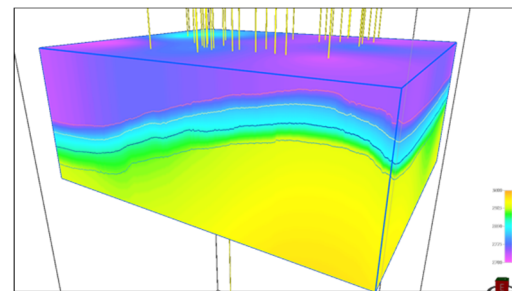


Fig.5 3D Spatial Velocity Model of Badaowan Formation of Jurassic System

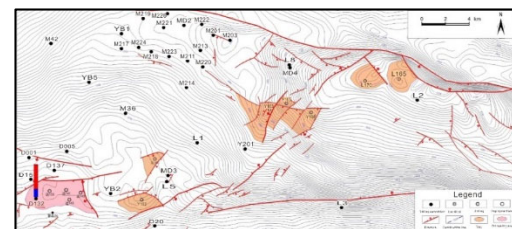


Fig.6 Top Boundary Structure of Jurassic Badaowan Formation I in Madong Area

3. Analysis of reservoir forming characteristics

The Jurassic Badaowan Formation in Madong area is a braided river delta deposit, in which thick sand bodies are developed in the Bayi Member, which is a favorable reservoir development section. The physical properties of sand bodies are gradually getting better from west to east. The stable mudstone section of the Ba'er Member and

Sangonghe Formation can be used as the regional cap rock of the reservoir section of the Badaowan Formation, forming a stable reservoir cap combination. The oil and gas of Badaowan Formation in the study area mainly come from Permian source rocks. How did oil and gas migrate to the Bayi Member to form reservoirs? The study shows that there are three major dredging systems for oil and gas migration in this area: vertically, there are deep and shallow oil source faults (Fig.7); Horizontally, there are regional unconformities between Carboniferous and Permian, Permian and Triassic, and Triassic and Jurassic in three stages. At the same time, permeability sand bodies with good continuity are also developed laterally, so that deep oil and gas migrate vertically through deep and shallow fault systems, and laterally through unconformity surfaces and dominant reservoirs to the reservoir of Bayi Member.

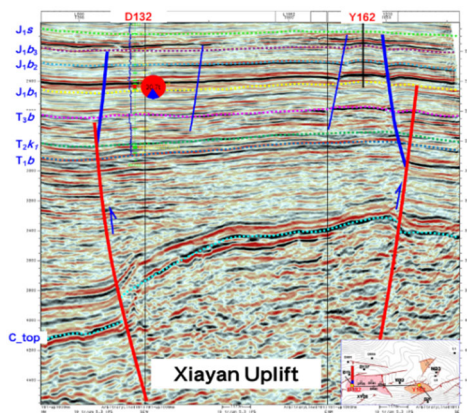


Fig.7 Seismic Geological Interpretation Profile of Well D132 and Y162

According to the analysis of oil and gas producing wells in Well D132 and Well YT1 Badaowan Formation, both of them are fault controlled structural reservoirs in the context of ancient uplift, and the trap types are fault nose and fault block structures. Therefore, the effective configuration of deep multistage oil source faults and inherited ancient uplift determine the early oil and gas enrichment[6-7], and micro-relief fault blocks and fault nose traps control the final gathering place of oil and gas. Madong area is characterized by multi-stage accumulation: oil and gas are gradually uplifted from south to north in a "ladder" manner. The ancient uplift and deep fault control the distribution and enrichment of deep medium shallow oil and gas reservoirs in Madong, presenting a multi-stage adjustment of oil and gas and a stepped three-dimensional reservoir formation model (Fig.8).

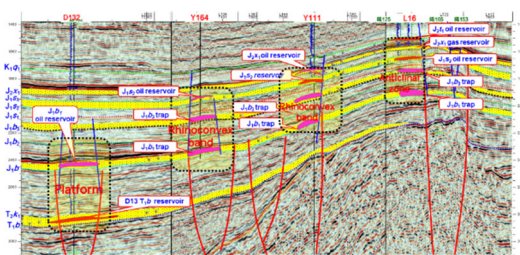


Fig.8 Trap and Reservoir Distribution Profile

Therefore, the favorable reservoir formation configuration of Badaowan Formation in Madong area is deep and shallow oil source fault and basement ancient uplift and current reliable trap. Deep and shallow faults are mutually configured to form three favorable oil and gas accumulation zones: Dabasong uplift, Xiayan uplift and Sangequan uplift anticline zone. The favorable trap zones are locked in Xiayan uplift zone and Sangequan uplift anticline zone (Fig.9).

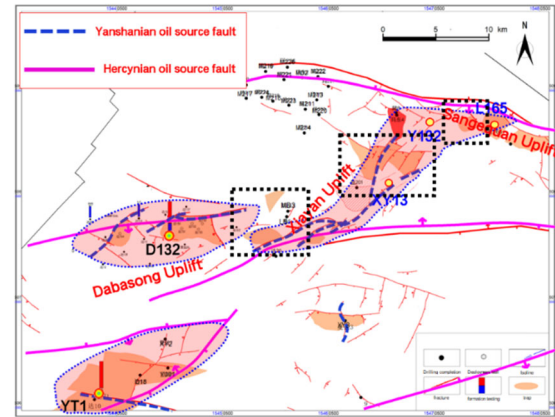


Fig.9 Distribution of Deep and Shallow Fault Systems in Madong Area (Superimposed J1b Trap and J1s Reservoir)

4. Conclusion

- (1) The Jurassic Badaowan Formation in Madong area has a macro structural pattern of "high in the north and low in the south", "two bulges, one anticline and one platform"; Badaowan Formation can be divided into the first, second and third members of Badaowan Formation from bottom to top; The thickness of the stratum gradually decreases from west to east.
- (2) Jurassic Badaowan Formation in Xiayan fault zone is braided river delta deposit, underwater distributary channel sand body in delta front of Bayi Member is favorable reservoir development interval, and thick mudstone of Bayi Member and Sangonghe Formation is regional effective cap rock, forming good reservoir and cap combination.
- (3) Systematically sort out the relationship between the deep and shallow fault system, oil and gas dredging and allocation of Badaowan Formation in Madong area, and in combination with the distribution characteristics of ancient uplifts, it is clear that the deep oil and gas are relay adjusted along the deep and shallow faults, and the large fault zone and the inherited uplift zone are the favorable oil and gas accumulation areas of Badaowan Formation. The study shows that Badaowan Formation has a multi-stage adjustment of oil and gas and a stepwise three-dimensional reservoir formation model. It is pointed out that Dabasong uplift, Xiayan uplift and Sangequan uplift anticline belt are three favorable oil and gas accumulation belts.

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